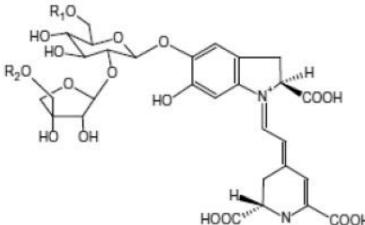
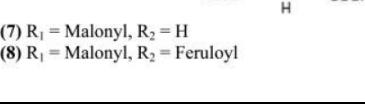
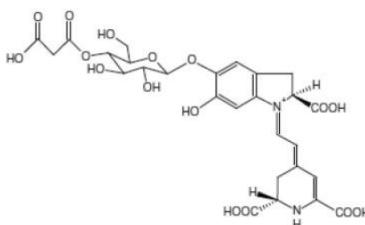
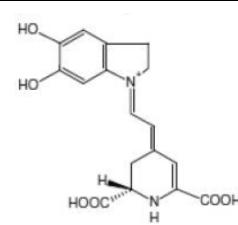
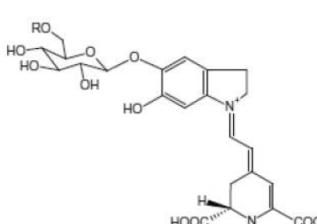
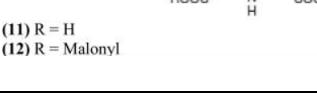
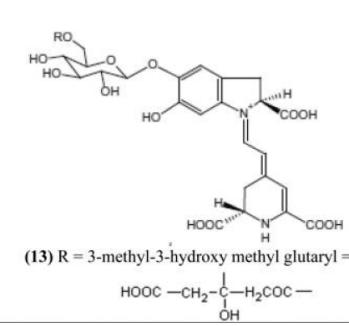


Table S1.

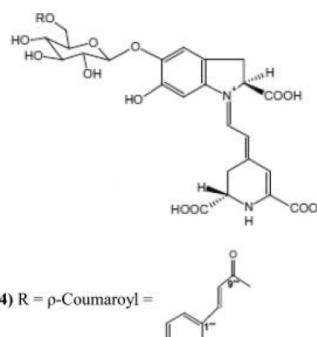
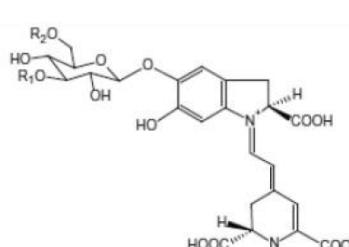
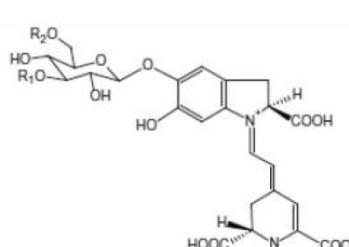
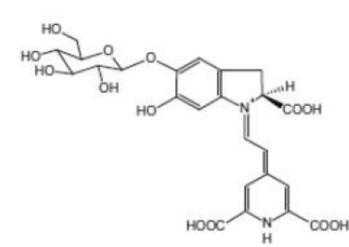
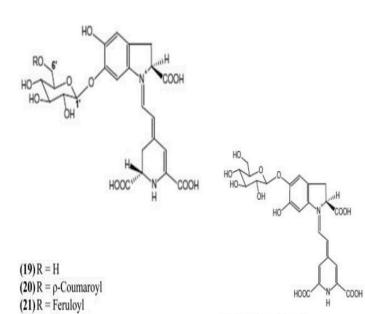
Structures and Absorption Maxima of Betacyanins. Based on [49], modified.

Compound	Source	Structure	Absorption maximum [nm]	Reference(s)
Betanidin (1) CAS 2181-76-2	<i>Beta vulgaris</i> L.		541	[340]
Betanin (2) CAS 7659-95-2	<i>Beta vulgaris</i> L.; <i>Ullucus tuberosus</i> Caldas		537; 535	[341] [66, 342]
2'-O-Apiosyl-betanin (3) 2'-O[5''-O-(E)-feruloyl]-apiosyl-betanin (4) 2'-O[5''-O-(E)-sinapoyl]-apiosyl-betanin (5)	<i>Phytolacca americana</i> L.		539 331, 548	[343] [30, 344]
Phyllocactin (6) Betanidin-5-O-(6'-O-malonyl)-β-glucoside CAS 15167-85-8	<i>Phyllocactus hybridus</i> Hort.; <i>Ullucus tuberosus</i> Caldas		539 535	[160] [342]

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2'-O-apiosyl-phyllocaclin (7)	<i>Christmas cactus</i> <i>Schlumbergera x buckleyi</i>		538	[345]
2'-O-[5''-O-(E)-feruloyl]-apiosyl-phyllocaclin (8)			328, 549	[344]
4'-O-Malonyl-betanin (9)	<i>Hylocereus ocamponis</i> Britton & Rose		538	[343]
2-Descarboxybetanidin (10)	<i>Carpobrotus acinaciformis</i> (L.) L.Bolus		533	[66]
2-Descarboxybetanin (11)	<i>Beta vulgaris</i> L.		532	[66]
6'-O-Malonyl-2-descarboxybetanin (12)	<i>Beta vulgaris</i> L.		535	[66]
Hylocerenin (13) CAS 403517-96-4	<i>Hylocereus polyrhizus</i> (F.A.C. Weber) Britton & Rose		541	[69]

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Lampranithin I (14) Lampranithin II (15)	<i>Lampranthus</i> sp. <i>Lampranthus</i> sp.		290, 320, 538 288, 322, 538	[346] [346, 347]
Prebetanin (16) CAS 13798-16-8	<i>Beta vulgaris</i> L. <i>Phytolacca americana</i> L.		538	[344]
Rivinianin (17) CAS 58115-21-2	<i>Rivina humilis</i> L.		235, 541	[348, 349]
Neobetanin (18)	<i>Beta vulgaris</i> L.		267, 306, 470	[67]
Gomphrenin I (19) Gomphrenin II (20) Gomphrenin III (21)	<i>Gomphrena globosa</i> L. <i>Gomphrena globosa</i> L. <i>Gomphrena globosa</i> L. <i>Ullucus tuberosus</i> Caldas <i>Gomphrena globosa</i> L.		543 550; 547 550	[350] [237, 342] [351] [16]
Gomphrenin IV (22)			(18) R <sub>1</sub> = glucosyl, R <sub>2</sub> = H	

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Amaranthin (23) CAS 15167-84-7	<i>Celosia cristata</i> L.		536	[65, 80]
Iresinin I (25) CAS 78413-55-5	<i>Iresine herbstii</i> Hook.		298, 540	[352]
Celosianin I (25)	<i>Celosia argentea</i> L. var. <i>cristata</i>		306, 546	[352]
Celosianin II (26) CAS 114847-18-6	<i>Celosia argentea</i> L. var. <i>cristata</i>		312, 546	[352]
Sinapoylamaranthin (27)	<i>Gomphrena globosa</i> L.		540	[16]

(23) R<sub>1</sub> = H, R<sub>2</sub> = H  
(24) R<sub>1</sub> = H, R<sub>2</sub> = 3-hydroxy-3-methyl glutaryl = H<sub>3</sub>C—CH<sub>2</sub>—C(H)—H<sub>2</sub>COC — OH  
(25) R<sub>1</sub> = H, R<sub>2</sub> = p-Coumaroyl  
(26) R<sub>1</sub> = H, R<sub>2</sub> = Feruloyl  
(27) R<sub>1</sub> = H, R<sub>2</sub> = Sinapoyl

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Bougainvillein-r I (28) CAS 30513-63-4	<i>Bougainvillea</i> ssp.		538	[13, 250]
Bougainvillein-r III (28)	<i>Bougainvillea</i> ssp.		312, 541	[353]
Feruloyl- bougainvillein-r I (28)	<i>Ullucus tuberosus</i> Caldas		534	[17]

(28) R = H  
(29) R = p-Coumaroyl  
(30) R = Feruloyl

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Mammillarinin (31) 4'-O-(E)-Malonyl- bougainvillein-r I (32)	<i>Mammillaria</i> ssp.		539	[349]
	<i>Mammillaria</i> ssp.		538	[349]

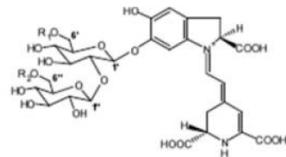
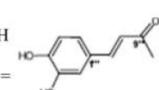
(31) R<sub>1</sub> = H, R<sub>2</sub> = Malonyl  
(32) R<sub>1</sub> = Malonyl, R<sub>2</sub> = H

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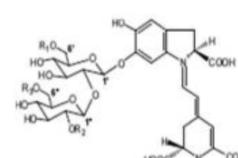
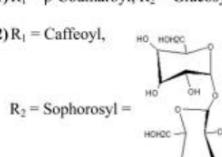
2-Descarboxy- mammillarinin (33)	<i>Mammillaria</i> ssp.		533	[349]
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(33) R = Malonyl

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<i>Bougainvillea glabra</i> Choisy	316, 545	[112]
<i>Bougainvillea glabra</i> Choisy	306, 540	[112]
Bougainvillein-v (34) 6'-O-(E)-Caffeoyl- Bougainvillein-v (35) 6'-O-(E)-p-Coumaroyl- Bougainvillein-v (36) 6''-O-(E)-p-Coumaroyl- Bougainvillein-v (37) 6',6''-di-O-(E)-p-Coumaroyl- Bougainvillein-v (38) 6''-O-Ramnosyl- Bougainvillein-v (39)	 (34) R <sub>1</sub> = H, R <sub>2</sub> = H (35) R <sub>1</sub> = caffeoyl =  , R <sub>2</sub> = H	306, 540
<i>Bougainvillea glabra</i> Choisy	307, 548	[112]

<i>Bougainvillea glabra</i> Choisy var. <i>sanderiana</i>	541	[355]
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<i>Bougainvillea glabra</i> Choisy	312, 547	[112]
2''-O{[6'-O-(E)-Caffeoyl]- [6''-O-(E)-p-coumaroyl]}- glucosyl- bougainvillein-v (40)		
2''-O[6,6''-di-O-(E)- coumaroyl]-glucosyl- bougainvillein-v (41)	(40) R <sub>1</sub> = Caffeoyl, R <sub>2</sub> = Glucosyl, R <sub>3</sub> = p-Coumaroyl (41) R <sub>1</sub> = p-Coumaroyl, R <sub>2</sub> = Glucosyl, R <sub>3</sub> = p-Coumaroyl	307, 548
2''-O{[6'-O-(E)-Caffeoyl]- [6''-O-(E)-p-coumaroyl]}- sophorosyl- bougainvillein-v (42)	(42) R <sub>1</sub> = Caffeoyl, R <sub>2</sub> = Sophorosyl =  R <sub>3</sub> = p-Coumaroyl	312, 549

Isobetanin-5-O- $\beta$ -glucoside	<i>Ullucus tuberosus</i> Caldas	535	[342]
Dehydro-phyllocaclin	<i>Ullucus tuberosus</i> Caldas	538	[342]
Dehydro-isophyllocaclin	<i>Ullucus tuberosus</i> Caldas	537	[342]
Betanidin-5-O-(4'-O-malonyl- $\beta$ -glucoside)	<i>Ullucus tuberosus</i> Caldas	535	[342]
Isobetanidin-5-O-(6'-O-malonyl)- $\beta$ -glucoside (isophyllocaclin)	<i>Ullucus tuberosus</i> Caldas	535	[342]
Isobetanidin-5-O-(4'-O-malonyl)- $\beta$ -glucoside	<i>Ullucus tuberosus</i> Caldas	535	[342]
2-Decarboxy-phyllocaclin	<i>Ullucus tuberosus</i> Caldas	533	[342]
Betanidin-feruloyl-5-O- $\beta$ -diglucoside	<i>Ullucus tuberosus</i> Caldas	533	[342]
Isobetanidin-feruloyl-5-O- $\beta$ -diglucoside	<i>Ullucus tuberosus</i> Caldas	532	[342]
Betanidin-5-O-(6'-O-feruloyl)- $\beta$ -glucoside (lampranthin II)	<i>Ullucus tuberosus</i> Caldas	540	[342]
Isobetanin-5-O-(6'-O-feruloyl)- $\beta$ -glucoside (isolampranthin II)	<i>Ullucus tuberosus</i> Caldas	540	[342]
Isobetanin-6-O-(6'-O-feruloyl)- $\beta$ -glucoside (isogomphrenin III)	<i>Ullucus tuberosus</i> Caldas	547	[342]

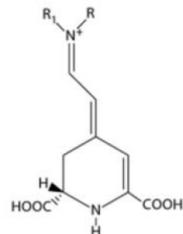
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Table S2. Structures and Absorption Maxima of Betaxanthins. From [49], modified

General formula:



Pigment	Source	R	R1	Absorption maximum [nm]	References
Indicaxanthin CAS 2181-75-1	<i>Opuntia ficus-indica</i> L.		Proline	260, 305, 485	[9, 356]
Portulacaxanthin I CAS 11042-69-6	<i>Portulaca grandiflora</i> Hook. <i>Opuntia ficus-indica</i> L.		Hydroxyproline	483	[62, 357]
Portulacaxanthin II CAS 135545-98-1	<i>Portulaca grandiflora</i> Hook. <i>Beta vulgaris</i> L.	H	Tyrosine	468	[14, 24]
Portulacaxanthin III	<i>Portulaca grandiflora</i> Hook. <i>Beta vulgaris</i> L.; <i>Ullucus tuberosus</i> Caldas	H	Glycine	470 469	[14, 24] [342]
Vulgaxanthin I CAS 904-62-1	<i>Beta vulgaris</i> L.; <i>Ullucus tuberosus</i> Caldas	H	Glutamine	470 467	[9, 358] [342]
Vulgaxanthin II CAS 1047-87-6	<i>Beta vulgaris</i> L.	H	Glutamic acid	469	[14, 358]
Vulgaxanthin III	<i>Beta vulgaris</i> L. var. <i>lutea</i> <i>Beta vulgaris</i> L. ssp. <i>cicla</i>	H	Asparagine	470 457	[14] [322, 359]
Vulgaxanthin IV	<i>Beta vulgaris</i> L. var. <i>lutea</i> <i>Beta vulgaris</i> L. ssp. <i>cicla</i>	H	Leucine	470	[14, 359]
Miraxanthin I CAS 5296-79-7	<i>Mirabilis jalapa</i> L.	H	Methionine sulfoxide	475	[4, 360]

Miraxanthin II CAS 5375-63-3	<i>Mirabilis jalapa</i> L.	H	Aspartic acid	477	[4, 360]
Miraxanthin III CAS 5589-85-5	<i>Mirabilis jalapa</i> L.	H	Tyramine	473.5	[4, 14]
3-Methoxytyramine-Bx	<i>Mirabilis jalapa</i> L. <i>Celosia argentea</i> L. var. <i>cristata</i>	H	3-Methoxytyramine	461	[4, 80]
Miraxanthin V CAS 5375-64-4	<i>Mirabilis jalapa</i> L. <i>Beta vulgaris</i> L. <i>Celosia argentea</i> L. var. <i>cristata</i>	H	Dopamine	475.5	[4, 66]
Histamine-Bx	<i>Mirabilis jalapa</i> L. <i>Beta vulgaris</i> L.	H	Histamine	468	[4, 14]
Dopaxanthin CAS 71199-31-0	<i>Glotiphyllum</i> <i>longum</i> (Haw.) N.E.Br.	H	L-DOPA	472	[63]
Humilixanthin CAS 111534-70-4	<i>Rivina humilis</i> L.	H	Hydroxynorvaline	258, 463, 483	[361]
$\alpha$ -Aminobutyric acid-Bx	<i>Beta vulgaris</i> L.	H	$\alpha$ -Aminobutyric acid	459	[9]
Methylated arginine-Bx	<i>Amaranthus</i> <i>tricolor</i> L.	H	Methyl derivative of arginine	478	[362]
(S)-Tryptophan-Bx	<i>Celosia argentea</i> var. <i>cristata</i>	H	(S)-Tryptophan	218, 264, 471	[196]
Serine-Bx	<i>Beta vulgaris</i> L.	H	Serine	468	[9]
Valine-Bx	<i>Beta vulgaris</i> L.	H	Valine	470	[9]
Phenylalanine-Bx	<i>Beta vulgaris</i> L.	H	Phenylalanine	472	[9]
Isoleucine-Bx	<i>Beta vulgaris</i> L.	H	Isoleucine	470	[9]
Alanine-Bx	<i>Beta vulgaris</i> L. ssp. <i>cicla</i> [L.]	H	Alanine	468	[14]
Musca-aurin I CAS 52012-51-8	<i>Amanita</i> <i>muscaria</i> (L.) Lam.)	H	Ibotenic acid		[27, 28]
Muscimol-Bx	<i>Amanita</i> <i>muscaria</i> (L.) Lam.)	H	Muscimol	214, 264, 469	[28]
4,5-Dihydromuscimol-Bx	<i>Amanita</i> <i>muscaria</i> (L.) Lam.)	H	4,5-Dihydromuscimol	260, 466	[28]
Musca-aurin II CAS 12624-17-8	<i>Amanita</i> <i>muscaria</i> (L.) Lam.)	H	Stizolobic acid	196, 260, 473	[27, 28]
Musca-aurin VII CAS 81943-08-0	<i>Amanita</i> <i>muscaria</i> (L.) Lam.) <i>Beta vulgaris</i> L. ssp. <i>cicla</i> [L.]	H	Histidine	472	[14, 27]
Methionine-Bx	<i>Opuntia</i> sp.	H	Methionine	477	[364]
Threonine-Bx	<i>Beta vulgaris</i> L. ssp. <i>cicla</i> [L.]; <i>Ullucus</i> <i>tuberosus</i> Caldas	H	Threonine	469 465	[324, 364]

Arginine-Bx	<i>Gomphrena globosa</i> L.; <i>Ullucus tuberosus</i> Caldas	H	Arginine	469 470	[16] [342]
Lysine-Bx	<i>Gomphrena globosa</i> L.	H	Lysine	458	[17]
Ethanolamine-Bx	<i>Beta vulgaris</i> L. ssp. <i>cicla</i> [L.]	H	Ethanolamine	460	[364]
Putrescine-Bx	<i>Bougainvillea</i> ssp.	H	Putrescine	461	[16]
Phenylethylamine-Bx	<i>Opuntia</i> ssp.	H	Phenylethylamine	475	[357]

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Table S3. Quantum Yield  $\Phi$  of Fluorescence of Betalains

Betalain	CAS number	$\Phi$ in water	$\Phi$ in methanol	$\Phi$ in ethylene glycol	Reference
Betanin	7659-95-2	0.0007	0.0013	0.0047	[79]
Indicaxanthin	2181-75-1	0.0053	0.0081	0.033	[79]
Vulgaxanthin I	904-62-1	0.0073	0.011	0.039	[365]
Miraxanthin V	5375-64-4	0.003	0.0047	0.015	[366]
Miraxanthin I	5296-79-7	0.0084	-	-	[80]

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Table S4. Fluorescence Properties of Some Betalain Pigments. From [47], modified.

Betalain	CAS number	Amino acid	$\lambda_{\text{ex}}$ (nm)	$\lambda_{\text{em}}$ (nm)	Stokes shift (nm)	Reference
Betanin	7659-95-2		535	608	73	[328]
Indicaxanthin	2181-75-1	Pro	463	515	52	[6, 74]
Vulgaxanthin I	904-62-1	Gln	464	509	45	[6, 74]
Vulgaxanthin II	1047-87-6	Glu	466	508	42	[74]
Dopaxanthin	71199-31-0	DOPA	463	510	47	[6, 74]
Miraxanthin I	5296-79-7	MetSO	475	509	34	[74]
Miraxanthin II	5375-63-3	Asp	474	507	33	[74]
Miraxanthin III	5589-85-5	tyramine	464	506	42	[74]
Miraxanthin V	5375-64-4	dopamine	465	512	47	[6, 74]
Musca-aurin VII	81943-08-0	His	465	509	44	[74]
Portulacaxanthin II	135545-98-1	Tyr	474	509	35	[6, 74]
Alanine-Bx		Ala	463	508	45	[74]
Methionine-Bx		Met	464	509	45	[74]
Vulgaxanthin IV		Leu	464	509	45	[74]
Phenylalanine-Bx		Phe	464	510	46	[74]
Phenelethylamine-Bx		phenelethylamine	473	551	78	[47]
		ethylamine	472	548	76	[47]
		propylamine	472	548	76	[47]
		N-methylethanamine	472	548	76	[47]
		N-methyl-N-propylamine	472	550	78	[47]
		pyrrolidine	471	549	78	[47]
		aniline	513	560	47	[47]
		N-methylaniline	494	553	59	[47]
		N-ethylaniline	494	554	60	[47]
		indoline	521	570	49	[47]
		(S)-indoline-2-carboxylic acid	529	575	46	[47]

Table S5. The Content of Betalains and Other Antioxidants in Various *Opuntia* ssp. Clones. According to [190], modified.

Cultivar	Total phenolics as gallic acid equivalents [mg/L]	Betaxanthins as indicaxanthin equivalents [mg/L]	Betacyanins as betalain equivalents [mg/L]	Ascorbic acid [mg/L]	TEAC		ORAC	
					Juice [mmol/L]	Pulp [mmol/kg]	Juice [mmol/L]	Pulp [mmol/kg]
Green	243 ± 13.4	0.4 ± 0.02	0.1±0.01	51.1±3.0	3.31±0.13	2.24±0.09	5.45	3.68
Orange	247 ± 23.1	76.3 ± 0.38	6.6±0.04	70.2±16.0	3.10±0.04	2.32±0.03	5.83	4.36
Red	335 ± 19.3	67.9 ± 0.19	120.0±0.44	67.9±16.5	3.71±0.47	2.60±0.33	6.35	4.44
Purple	660 ± 35.8	195.8 ± 0.46	431.0±1.04	95.4±0.6	4.99±0.37	3.64±0.27	11.20	8.16

Table S6. Some Food Applications of Betalains from Red Beetroot

Food product	Betalain additive	Results	Addition level (w/w)	Reference
Yoghurt	Beetroot powder into the yogurt	Optimal sensory acceptance, rheological, and physicochemical properties	2%	[367]
Ice cream	Beetroot juice	Decreased apparent viscosity, dry matter and overrun, but high biofunctional properties	2.5%, 5%, and 10%	[368]
Baked goods	Beetroot powder	Good hydration properties and viscometric properties of wheat dough, physical characteristics and sensory attributes of baked rolls	2–10%	[369]
Biscuits	Beetroot extract	Increased nutritional values, acceptability and bioactivities.	7	[370]
Jellies	Beetroot juice	Good quality jelly	Beetroot juice was heated with 2% pectin, 61% sugar, and 0.5% citric acid	[371]
Candies	Beetroot pomace	Improved phytochemical properties of the candies	9.24%	[372]
Chicken frankfurters	Beetroot juice concentrate	Good color stability without adversely affecting flavor or texture	0.48%	[373]
Pasta	Beetroot	Addition of beetroot can improve the quality of pasta, and render attractive color on the pasta	150 g/kg	[374]
Noodles	Beetroot pulp	Addition of beetroot improves the color, nutritional, and sensory properties of formulated noodles, and evokes an increment in antioxidant activity.	10–40% Noodles	[375]
Meat	Red beetroot powder	Increased antioxidant activity and extended shelf life	0.15%	[376]
Nondairy drinks	Fresh beetroot	Beetroot drink was a good product without cholesterol and contained health promoting components		[377]
Fish	Red beet peel extracts	Extension of the shelf life of rainbow trout, improved chemical and sensory quality of fish	0.1% (w/v) ice with red beet peel extracts	[378]
Sausages	Betalain powder from beetroot	The color of betalain-containing sausages proved to be more stable toward light exposure during storage than the color of those containing nitrite-nitrate salts	33, 45, 56 ppm	[379]

Beverages	Beetroot	Decreased nephrotoxicity	4 g/L	[380]
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